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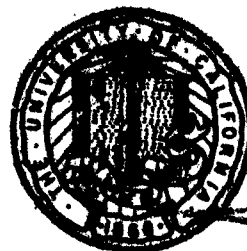
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San Diego 52, California

DIGITAL ENCODER AND PAPER TAPE PUNCH

EARL D. SQUIER

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MARINE PHYSICAL LABORATORY

MPL-U-25/62

DIGITAL ENCODER AND PAPER TAPE PUNCH

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ABSTRACT

An all solid-state digital recording system is described along with an example of its operation. The equipment consists of a 200-channel input scan switch, an analog to digital converter, and a paper tape punch.

Input voltages are encoded into 4-, 8-, or 12-bit words and punched on paper tape as 4-bit characters at rates up to 50 characters per second. Provisions are included for formatting the tape for use in the Bendix G15 computer.

I. INTRODUCTION

The data recording equipment to be described here was designed with its primary objective, the recording of data from the 32 directional beams of the Marine Physical Laboratory ambient sea noise measuring equipment. The possibility of using the equipment for other and varied recording problems was kept in mind, resulting in a flexible digital recording instrument.

II. GENERAL DESCRIPTION

The equipment shown in the photograph, Fig. 1, consists of a multiple input scan switch, an analog to digital converter, paper tape punch, and controlling electronics. Solid-state electronics is used throughout.

The equipment consists of 3 major units each housed in a 22' x 15' x 16' cabinet. These cabinets have hardware to allow them to be stacked, forming one unit.

The upper unit houses the input scan switch, a Vidar model 240dc voltage to frequency converter and a Computer Measurements Corporation model 1230A binary counter. The input scan switch allows a series of slowly changing voltages to be scanned in sequence. The analog to digital conversion is performed by the converter and binary counter. The converter produces a frequency proportional to the input voltage. The counter then makes a count of this frequency for a fixed period of time. The count is displayed in binary form by neon indicator lamps and is available for transfer to the storage register and paper tape punch.

The center unit is the main control chassis which is made up of Computer Control Co. SPAC series of digital modules and several special circuits. This unit contains circuits for generating the timing and controlling signals as well as circuits for gating and storage of the binary information prior to transfer to the perforator.

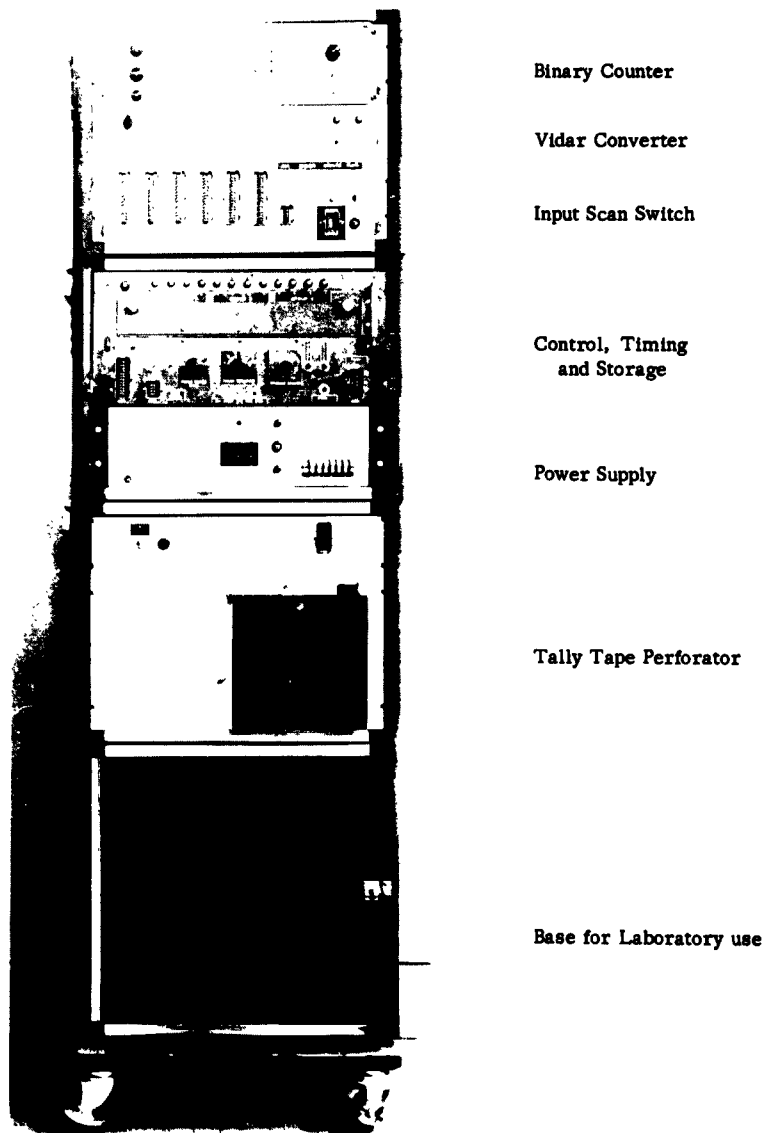


Fig. 1 Paper Tape Punch and Encoder

The lower unit houses a Tally model 420 tape perforator and Tally model 1424 transistorized drive package.

The equipment will scan any number of dc voltages up to 200, convert them to digital form and punch the digital information on 5-level paper tape. Four of the 5 levels are used to form 4-bit characters, the 5th level bit is entered whenever data is being punched. Words of 1, 2 or 3 characters can be punched for each input voltage measured.

Upon completion of the sampling of a series of input voltages, any one format character can be entered along with a length of tape leader. The equipment can be made to stop automatically after the input scan cycle has been completed, or will repeat the cycle until stopped externally.

The tape punching rate can be varied from a maximum of 50 characters per second to 1.6 per second. The upper limit is below the maximum rating of 60 per second specified for the Tally 420 perforator. The lower limit can be extended by use of an external time base.

The sensitivity and dynamic range can be adjusted to suit individual requirements by the use of the Vidar voltage range, the counting period, and the selection of 1-, 2- or 3-character words. See *Sensitivity and Range* under section IV.

The instrument can be used for sampling of a single channel voltage supplied directly to the converter. The dynamic voltage range of the equipment is greater with this method of operation because of the limited voltage range of the input scan switch.

III. SPECIFICATIONS

Scan Switch

Number of gates:	200 maximum.
Maximum input voltage:	8v when used from a 1K source and with a 1 meg load.
Linearity:	Shown on page
Variation in gates over 8v range:	±20 mv.

Converter

Voltage ranges;	0.1, 1.0, 10, 100 and 1000.
Input impedance:	100K on the 0.1v range. 1 meg on all other ranges. NOTE: Scan switch gates normally require the 1 meg load.
Time for change in output frequency:	1 cycle.
Linearity:	0.1%.
Drift:	Long term 0.1%.
Output:	Frequency proportional to input voltage. 100kc maximum on all voltage ranges.

Binary Counter

Gate times:	10, 20, 40, 80, 100, 200, 400, 800 and 1600 ms.
Read-out:	16 binary bits.

Tape Punching Periods

0.02, 0.04, 0.08, 0.16, 0.32 and 0.64 sec with internal time base.
--

Storage Register

12 binary bits.

Format

1-, 2- or 3-character data words of 4 data bits each.
1-character command word optional at the end of the input scan cycle.

Power Requirement

115v, 60 cycle, 3 amps.

Equipment Weight

Total -- 243 lbs.
Unit 1 - 87 lbs.
Unit 2 - 86 lbs.
Unit 3 - 70 lbs.

IV. DETAILED DESCRIPTION

Control Timing

The simplified block diagram, Fig. 2, shows the functional relationships of the major units of the equipment.

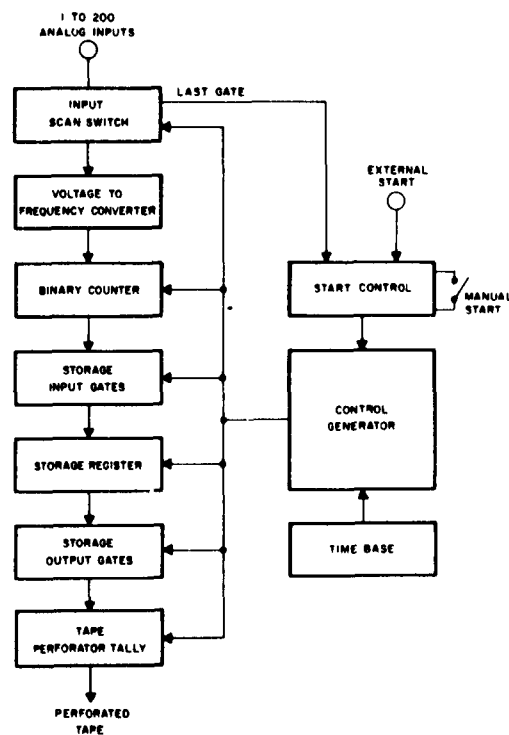


Fig. 2 Simplified Block Diagram

The time base unit generates the basic timing and clocking waveforms.

Proper signals from the time base are supplied to the control generator which inserts the necessary time delays for: scanning of the input voltage levels, storage, scanning of the store, and operation of the perforator. The control generator also synchronizes the start with the internal timing and allows for the format character to be punched at the proper time.

The input scan cycle can be started by either the manual start switch, located on the control chassis panel, or by an external 6 volt positive going pulse applied to the external start jack.

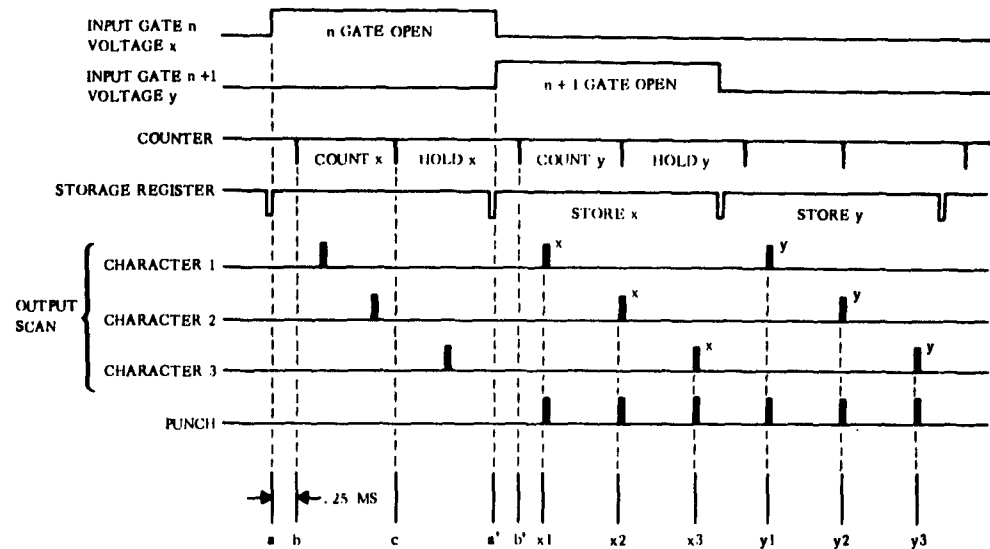
The start control forms the starting waveform and then locks out further start signals until reset.

Fig. 3 illustrates graphically the timing events of a 3-character per word scan.

After the start, the control generator opens the number one gate of the input scan switch and the converter produces a frequency proportional to the supplied voltage. After a 2.5 ms delay the binary counter gate is opened and the output of the converter is counted for a period of time determined by the counter gate, preselected by the operator. The counter holds the count until it is transferred to the store. At this time number two input gate is opened and the store is reset. After a delay of .2 ms the count now in the 16-bit binary counter (number one input voltage level) is transferred to the 12-bit storage register. The counter is then reset 2.5 ms later and a new counting cycle is started while the next input voltage is being measured. The count in the store is transferred sequentially to the punch in 4-bit characters, A, B and C, the 3 characters forming a 12-bit data word. One- or two-character words can also be selected by the punch sequence switch.

The cycle illustrated is then repeated until all input voltage levels have been scanned.

The cycle is stopped automatically at the end of an input scan cycle by the last gate opened by the input scan switch. The operation can also be stopped by the manual stop switch.



NOTE:

a	n GATE OPEN (INPUT VOLTAGE x)	a'	n + 1 GATE OPENS (INPUT VOLTAGE y)	x1 - x2 - x3	1 CHARACTER WORD x
b	COUNTER RESET . 25 MS FROM a		DELAY . 2 MS RESET STORAGE		TRANSFERRED TO PUNCH
c	COUNTER GATE CLOSSES		DELAY . 2 MS SET STORAGE	y1 - y2 - y3	3 CHARACTER WORD y
	COUNTER HOLDS COUNT		INPUT WORD x NOW IN STORE		TRANSFERRED TO PUNCH
		b'	COUNTER RESET 2.5 MS FROM a'		

Fig. 3 Repetitive Events During a 3-Character per Word Scan

When the recycle switch is in the ON position, the scan cycle will repeat one time after another once the operation is started.

Input Scan Switch Characteristics

The input scan switch consists of electronically controlled diode gates. These should be

supplied with signals from a *low* impedance resistive source. The gates will handle up to 8 volts. The curve shown in Fig. 4 shows the linearity of the gates operated from a 1 K ohm source. A group of 50 gates have been compared and a maximum difference in the output of ± 20 mv over the range 0-8 volts was observed.

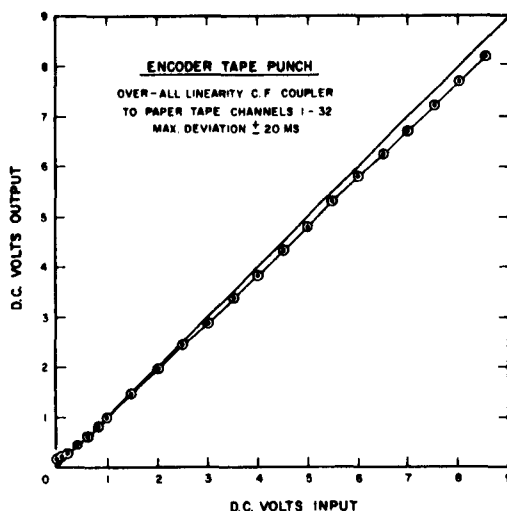


Fig. 4 Linearity Curve

Sensitivity and Range

The sensitivity and range of the equipment is determined in the analog to digital converter by the choice of converter voltage range and the binary counter gate time. Further control of the sensitivity and range after conversion is accomplished by the selection of the minimum value bit to be punched and the number of characters per word. A 1-character word has 16 units, a 2-character word has 256 units, and a 3-character word has 4096 units.

When the input scan switch is used the diodes impose an upper and lower limit on the input voltage. See *Input Scan Switch Characteristics*.

The counter gate time is a factor in determining the sensitivity of the equipment. The maximum counter gate time is limited by the conversion period. The conversion period must be at least 10 ms longer than the counter gate time which is the time necessary for circuit operation.

Data Conversion Rates

The internal time base generator will allow tape punching periods of .02, .04, .08, .16, .32 and .64 seconds. The conversion period is determined by the punch period and the number of characters per word to be punched.

$$\text{Punch Period} = \frac{\text{Conversion Period}}{\text{Characters per Word}}$$

Tape Format

The paper tape is punched with the Bendix G 15 digital computer coding. Four of the 5 levels are used to form 4-bit characters in a 1-2-4-8 hexadecimal code. The 5th level is entered whenever data is being punched. Data words of 1, 2 or 3 characters can be punched for each input voltage measured.

The absence of the 5th level indicates command or format characters. A 1-character format word will be punched at the end of the input scan cycle, when the format switch is ON. The format character is coded by the four switches.

The format character will be followed by a length of leader. There are two leader lengths available, either 1.25 inches or 7 inches, selected by a switch.

The words are punched on the tape one after another without spacing except for the leader that follows the format character.

External Control

A connector is provided for external control of the start, stop, format and recycle operation. The punch period, conversion period and input scan cycle waveforms are also available at this connection.

The data recording program can be placed under the control of external equipment by the use of this connector. Examples of the external control that might be used are counting of the data conversions, grouping of the data samples, or synchronizing with an external time base.

EXAMPLE: The proper combination of the various controls will be determined by the conditions of the signals to be recorded. The following is an example of the adjustments for one problem. Reference to the detailed description will help in understanding the example.

A voltage of 0 to 5 volts is to be recorded using 2-character words. (256 units, see *Sensitivity and Range*.) The 10-volt Vidar range would be used (the overload level would be 8 volts, see *Input Scan Switch Characteristics*). With the 5-volt input the Vidar would produce a frequency of 50 kc. Using the 10 ms counter gate would allow for a count of 500 ($50 \text{ kc} \times 10 \text{ ms}$) with each unit having a value of 10 mv ($5 \text{ V} \div 500$). If counter bits 2 through 9 were transferred to the storage register and punch, the range covered would be 0 to 5.12 volts in 20 mv units.

If the shortest punch period of 20 ms is used, the conversion period would be 40 ms (characters per word times punch period, see *Data Conversion Rates*). This will satisfy the requirement that the conversion period be at least 10 ms longer than the counter gate time.

V. SINGLE CHANNEL OPERATION

The previous discussion was concerned with the scanning of a number of signal voltages. Another possible mode of operation is the sampling of a single voltage, applied directly to the converter. The sampling is at conversion period rates determined by the control unit time base, either internal or external.

The sampling can be started and stopped by the manual start and stop buttons or by external pulses, refer to *Control Timing*, section IV.

Reference should be made to the Vidar model 240 manual.

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